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Steady seepage near an impermeable obstacle

A.R. Kacimov and A.N. Nicolaev

Institute of Mathematics and Mechanics, Kazan University, Kazan, Russia

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ABSTRACT

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The problem of an obstacle with maximum cross-sectional area has been analytically solved in terms of a model for 2-D seepage flow with a capillary fringe. The boundary of the obstacle appears to show a 'blunt configuration', that is, the pressure reaches its maximum value at the vertex and decreases monotonically downstream. With a sufficiently large size of obstacle, a positive pressure domain in the form of a 'bubble' is formed in the vicinity of its vertex. This result has been verified by computations for saturated–unsaturated flows in terms of the finite element method for the Richards equation. It has also been shown that an obstacle can transform the initial fully saturated flow into unsaturated flow inside the 'dry shadow' domain. The shape of an obstacle in a confined aquifer that provides a minimum water head drop has been determined within the scope of the Dupuit model. A 'critical cavity shape' has been found, i.e. a cavity for which the boundary is simultaneously an isobar and a stream line.

INTRODUCTION

Problems of disturbance in 'natural' groundwater flows are of great interest in various aspects of hydrogeology. As is customary, the initial flow in this case is assumed to be 1-D. The disturbing factor (such as a drain, a well, a trench, an obstacle or an accretion on a phreatic surface) increases the dimensionality of the problem. For steady-state flows, various techniques of analysis of disturbed flows are known: the Dupuit model (Strack, 1984), the model of a fully saturated flow with free surfaces in an unconfined aquifer (Hunt, 1972) or without free surfaces in a confined aquifer (Nelson, 1978) and the quasi-linear model for a partially saturated flow (Philip, 1990). In general, a design is developed taking account of the following questions: How much may the initial field of water head, pressure, moisture, stream function and velocity be distorted? What impact has the distorted flow on the disturbance

Correspondence to: A.R. Kacimov, Kazan University, Institute of Mathematics and Mechanics, NIIMM, University Str., 17, Kazan 420008, Russia.